EMFAC Modeling Change Technical Memo

SUBJECT: UPDATE TO HEAVY-DUTY VEHICLE EMISSIONS INVENTORY

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SUMMARY

Since the release of EMFAC2002, there has been considerable development in the area of heavy-duty vehicle (HDV) emissions inventory. One major advance is the Coordinated Research Council (CRC) E55/E59 project, which was sponsored by four governmental agencies and two private organizations and carried out jointly by CRC, Air Resources Board (ARB), and West Virginia University (WVU). Through the CRC E55/E59 project, not only were more emission test data on HDV obtained, but also test data were made available for trucks of the latest model years. In addition, the CRC E55/E59 project offered test data collected over the recently developed ARB 4-Mode Cycle (see below for further discussion). This has provided systematic idle emission data as well as emission data at several different speeds.

As a result, staff plans to update the heavy-duty vehicle emissions inventory to take advantage of the newly available test data and to reflect adopted regulations. This document will describe the CRC test data, present the revised HHDDT running exhaust emission factors, and propose new idle emissions and speed correction factors (SCFs) for HHDDTs.

Sources of HDV Emission Test Data

Emission test data used as the basis of the current HDV emissions inventory were acquired from several sources. The first three sets of data were obtained from New York State Department of Environmental Conservation and Energy (NYSDEC), WVU, and the Colorado Institute for Fuels and High Altitude Engine Research (CIFER). These data sets (hereafter referred to as the NWC data set) provided emission data collected from 23 HHDDTs and were used in the development of the emission factors for previous versions of EMFAC (for a detailed description of the three data sets and their analysis, refer to Section 10, *EMFAC2002 Technical Support Document* at www.arb.ca.gov/msei/on-road/latest_version.htm).

The most recent data set was obtained through the CRC E55/E59 project. The primary objective of the E55/E59 project is to quantify emissions from HDVs to support emissions inventory development. The project was designed to test a total of 75 HDVs, including 56 HHDTs, 15 medium heavy-duty diesel trucks (MHDDT), and 4 medium heavy-duty gasoline trucks (MHDGT). To date, 47 HHDDTs have been tested.

In the E55/E59 project, all HHDDTs were tested over the US Environmental Protection Agency's (USEPA) Urban Dynamometer Driving Schedule for Heavy-Duty Vehicles (UDDS;

also referred to as Test-D)[1]. In addition to the UDDS tests, all HHDDTs were tested over the ARB 4-Mode Cycle, which consists of an idle mode, a creep mode, a transient mode, and a cruise mode. Each mode characterizes a unique driving pattern in a whole trip of a truck. An additional mode, the High Speed Cruise mode, was also used during testing to obtain data points at 50 mph. Table 1 provides a summary of the ARB 4-Mode Cycle parameters, together with those of the High Speed Cruise mode and the UDDS cycle.

Table 1. Parameters of ARB 4-Mode Cycle and UDDS Cycle

Test Cycle/ Mode	Average Speed (mph)	Duration (seconds)	Length (miles)
Idle	0	600	N/A
Creep	1.8	253	0.12
Transient	15.4	668	2.85
Cruise	39.9	2,083	23.1
High Speed Cruise	50.2	757	10.5
UDDS	18.8	1063	5.55

Each truck in the CRC E55/E59 project was tested multiple times over the UDDS cycle and each mode of the ARB 4-Mode Cycle. The resulting vehicle specific HHDDT test data are listed in Appendix 1.

Heavy-Heavy Diesel Truck Emission Factors

In order to revise the HHDDT emission factors, the CRC data set was merged with the NWC data set for further analysis. The combined CRC-NWC data were plotted as a function of model year. The data points for each pollutant were then curve fit to determine the best regression equation that represented the overall emission trend.

Using regression equations, the emission rate for a given model year was calculated. Following the same model year grouping used in EMFAC2002, the calculated individual model year emission rates within a model year group were averaged.

In current EMFAC model, the zero-mile (ZM) emission and deterioration rates (DR) were determined using a model developed by Radian Corporation[2]. Although the CRC project provided extensive emission data, it has not collected sufficient information on tampering and malfunctions for staff to calculate ZM emission rates and DRs independent of the Radian model.

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[1] For a discussion of the UDDS, refer to 40 CFR Part 86 Subpart M.
[2] EMFAC Technical Support Document: Sec. 10. Heavy-Duty Truck Emission Factors Development (www.arb.ca.gov/msei/on-road/doctable_test.htm).

An analysis of the combined CRC-NWC data set indicates that, although the merge of the CRC and NWC data has resulted in changes in emission levels of individual model years, the characteristics of the emission trends of the NWC data remain unchanged. In Figures 1 and 2, the NOx and PM emission rates for the test vehicles from model years 1991 to 2002 , which were certified to similar emission standards, are plotted as a function of the cumulative mileages calculated from their ages. Also shown in the figures are the emission factors (i.e., the proposed ZM and current DR values) of the 1994-1997 model year group and 1999-2002 model year group. As the figures show, the combined CRC-NWC data suggest that the DRs currently used in EMFAC2002, which were developed using the NWC data and Radian model, adequately reflect the mileage-emission relationships of the combined CRC-NWC data.

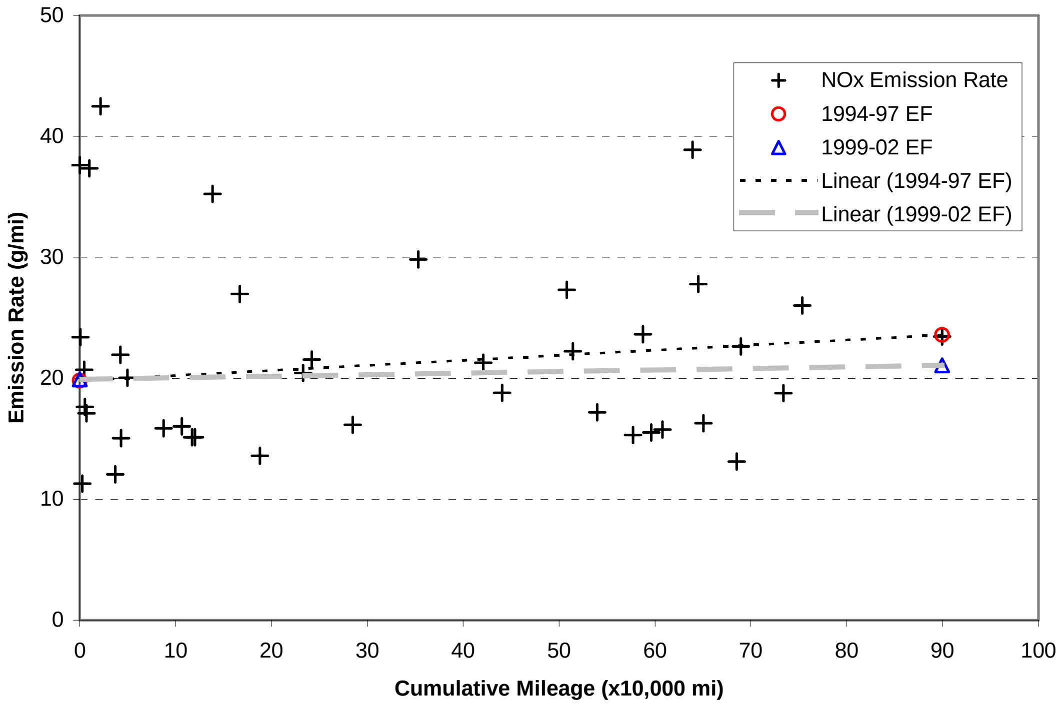


Figure 1. NOx Emission Rate vs. Cumulative Mileage for Test Vehicles

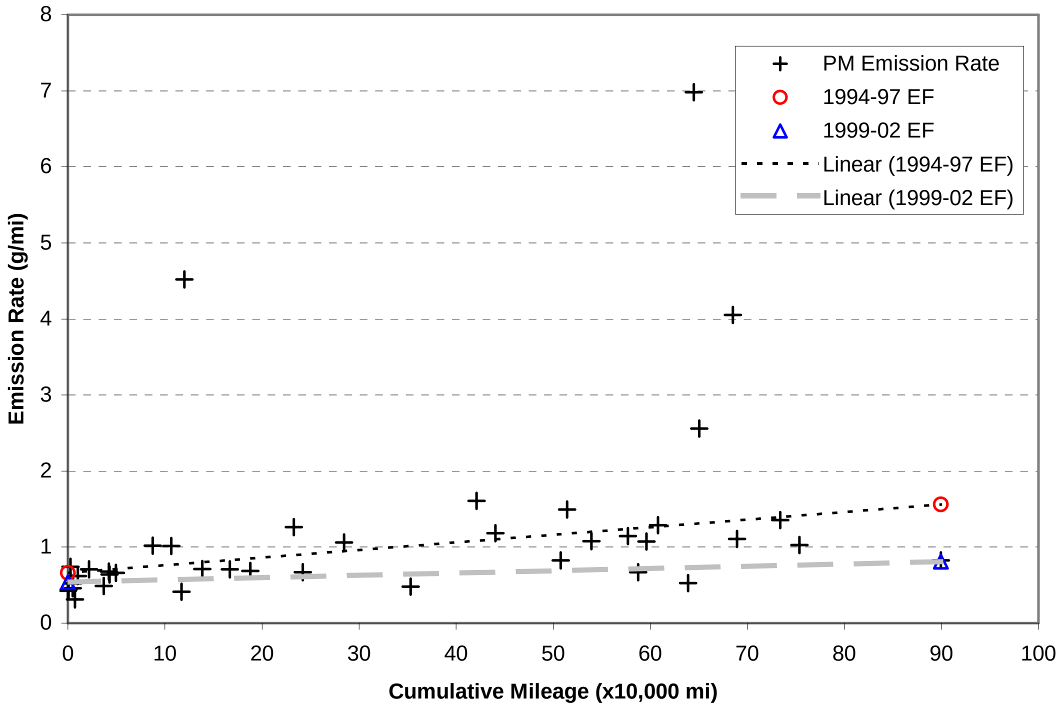


Figure 2. PM Emission Rate vs. Cumulative Mileage for Test Vehicles

As a result, staff has decided that only the ZM emission rates should be modified and no change is to be made to the DRs at this time. For each model year group, a ratio was calculated using the average emission rate based on combined CRC and NWC data versus the average emission rate based on only NWC data. The ratios were then used to modify the ZM rates of EMFAC2002. Tables 2 and 3 show the current and proposed emission factors for HHDDTs. It should be noted that the ZM rates and DRs for the post-1998 model year groups were estimated from 1998 model year group using the ratio-of-standard method.

Table 2. EMFAC2002 HHDDT Zero-Mile Emission Rates (ZM, g/mi) & Deterioration Rate (DR, g/mi/10,000mi)

Model Year Group	HC		CO		NOx		PM	
	ZM	DR	ZM	DR	ZM	DR	ZM	DR
Pre 1975	1.60	0.018	8.36	0.095	28.5	0.012	1.98	0.016
1975-76	1.45	0.018	7.81	0.098	27.2	0.013	1.85	0.016
1977-79	1.45	0.019	7.81	0.101	27.2	0.013	1.85	0.017
1980-83	1.45	0.020	7.81	0.108	27.2	0.014	1.85	0.018
1984-86	0.74	0.011	4.87	0.074	20.2	0.011	1.18	0.012
1987-90	0.34	0.009	2.48	0.065	16.8	0.015	0.84	0.008
1991-93	0.28	0.009	1.74	0.056	16.0	0.030	0.51	0.009
1994-97	0.19	0.016	0.84	0.068	19.1	0.042	0.32	0.010
1998	0.18	0.014	0.63	0.049	23.0	0.037	0.26	0.007
1999-02	0.18	0.009	0.63	0.031	13.4	0.013	0.21	0.003
2003	0.14	0.003	1.01	0.023	6.68	0.007	0.26	0.003
2004-06	0.14	0.003	1.01	0.023	6.68	0.007	0.26	0.003
2007-09	0.090	0.003	0.65	0.023	3.67	0.007	0.026	0.003
2010+	0.039	0.003	0.28	0.023	0.67	0.007	0.026	0.003

Table 3. Proposed HHDDT Zero-Mile Emission Rates (ZM, g/mi) & Deterioration Rate (DR, g/mi/10,000mi)

Model Year Group	HC		CO		NOx		PM	
	ZM	DR	ZM	DR	ZM	DR	ZM	DR
Pre 1975	1.90	0.018	12.3	0.095	28.2	0.012	3.09	0.016
1975-76	1.73	0.018	11.2	0.098	26.9	0.013	2.78	0.016
1977-79	1.51	0.019	10.0	0.101	25.5	0.013	2.41	0.017
1980-83	1.25	0.020	8.36	0.108	23.9	0.014	1.94	0.018
1984-86	1.02	0.011	6.96	0.074	22.6	0.011	1.56	0.012
1987-90	0.63	0.009	4.46	0.065	21.2	0.015	1.32	0.008
1991-93	0.52	0.009	3.65	0.056	19.6	0.030	0.89	0.009
1994-97	0.30	0.016	2.18	0.068	19.8	0.042	0.66	0.010
1998	0.25	0.014	1.15	0.049	25.5	0.037	0.39	0.007
1999-02	0.24	0.009	1.65	0.031	19.9	0.013	0.54	0.003
2003	0.25	0.003	1.31	0.023	14.2	0.007	0.50	0.003
2004-06	0.25	0.003	1.31	0.023	14.2	0.007	0.50	0.003
2007-09	0.16	0.003	0.84	0.023	7.81	0.007	0.050	0.003
2010+	0.069	0.003	0.37	0.023	1.42	0.007	0.050	0.003

A comparison between the 500,000-mile composite emission factors based on the current and proposed zero-mile emission rates are provided in Table 4.

Table 4. Comparison of Composite Emission Factors at 500,000 Miles Based on EMFAC2002 ZM and Proposed ZM (g/mi)

Model Year Group	Based on EMFAC2002 ZM				Based on Proposed ZM			
	HC	CO	NOx	PM	HC	CO	NOx	PM
Pre 1975	2.50	13.1	29.1	2.78	2.80	17.1	28.8	3.89
1975-76	2.35	12.7	27.8	2.65	2.63	16.1	27.6	3.58
1977-79	2.40	12.9	27.8	2.70	2.46	15.1	26.2	3.26
1980-83	2.45	13.2	27.9	2.75	2.25	13.8	24.6	2.84
1984-86	1.29	8.57	20.7	1.78	1.57	10.7	23.2	2.16
1987-90	0.79	5.73	17.5	1.24	1.08	7.71	22.0	1.72
1991-93	0.73	4.54	17.5	0.96	0.97	6.45	21.1	1.34
1994-97	0.99	4.24	21.2	0.82	1.10	5.58	21.9	1.16
1998	0.88	3.08	24.9	0.61	0.95	3.60	27.4	0.74
1999-02	0.63	2.18	14.0	0.36	0.69	3.20	20.6	0.69
2003	0.29	2.16	7.03	0.41	0.40	2.46	14.6	0.65
2004-06	0.29	2.16	7.03	0.41	0.40	2.46	14.6	0.65
2007-09	0.24	1.80	4.02	0.18	0.31	1.99	8.16	0.20
2010+	0.19	1.43	1.02	0.18	0.22	1.52	1.77	0.20

Table 4 shows that in general the proposed emission rate revision increases the emission rates of late model year groups more than older model year groups. This is particularly evident in the case of NOx for 2003 and later model years. As a result, while the emissions inventories calculated from the proposed emission rates would be higher than those estimated using the current EMFAC emission rates, more impact would be seen for future year inventories, as illustrated in Table 5.

Table 5. Estimated Impact to HHDDT Running Exhaust Emissions from Proposed Emission Rates (summer season, tpd)

Air Basin	Pollutant	2010			2020		
		Current	Proposed	Change	Current	Proposed	Change
San Joaquin Valley	HC	2.38	2.73	15%	1.41	1.56	10%
	CO	12.21	14.29	17%	8.88	9.77	10%
	NOx	55.25	79.31	44%	18.58	29.24	57%
	PM	1.14	1.52	34%	0.62	0.71	14%
South Coast	HC	3.72	4.34	17%	2.25	2.53	13%
	CO	20.67	24.38	18%	15.01	16.79	12%
	NOx	122.37	180.40	47%	38.80	63.50	64%
	PM	2.05	2.78	36%	1.13	1.31	16%

[Note: The final document will include impacts for the San Francisco, Sacramento, San Diego air basins for 2002 and 2015.]

HHDDT Speed Correction Factors

Current speed correction factors (SCF) for HHDDTs in EMFAC were inherited from U.S. EPA's MOBILE model. In the CRC E55/E59 project, HHDDTs were tested over the ARB 4-mode cycle and therefore emissions data at sevarel different speeds were obtained. Using these data, new SCFs were developed for HHDDTs.

An analysis of the CRC data suggests that for each pollutant different SCFs should be developed for two broad model year groups. Individual truck data on an emission vs. speed chart revealed that the plotted curves of individual model years tended to cluster into one of the two groups: a group including pre-1991 and 2000+ (2000 and later) model years and a group of 1991-1999 model years. The 1991-1999 model year group appears to be significantly different from the pre-1991 and 2000+ model year group. Staff interprets this apparent divergence of 1991-1999 group from the other groups as attributable to so-called off-cycle NOx emissions. That is, the programmed increase in NOx emissions of the trucks manufactured in the the 1990s.

Therefore, two sets of SCFs were calculated for the pre-1991/2000+ model year group and 1991-1999 model year group, respectively. For each group, emission data of a given pollutant were first normalized to the corresponding emission values of the UDDS cycle and the normalized emission values were then plotted as a function of speed. Regression curves were then fit to find the equations representing the characteristics of the data. The SCF for a given pollutant can be calculated from the following equation:

$$SCF = A + B*(Speed) + C*(Speed)^2 + D*(Speed)^3 + E*(Speed)^4 \quad (1)$$

Table 6 lists the parameters of the best fit equations for calculating the SCFs. A comparison between the proposed SCFs and the current EMFAC SCFs are given in Appendix 3. Note that in the case of HC and NOx, it was found that for both model year groups the data were better fit when different equations were used for the two specified speed domains.

Table 6. Equation Parameters for Proposed HHDDT SCFs

	Model Year Group	Speed (mph)	A	B	C	D	E
HC	Pre-91&2000+	0-18.8	7.245	-0.502	9.07×10^{-3}	--	--
		18.8-65	1.571	-0.036	2.84×10^{-4}	--	--
	1991-1999	0-18.8	12.72	-1.111	2.59×10^{-2}	--	--
		18.8-65	2.511	-0.102	1.18×10^{-3}	--	--
NOx	Pre-91&2000+	0-18.8	2.891	-0.196	5.05×10^{-3}	--	--
		18.8-65	1.329	2.22×10^{-2}	2.33×10^{-4}	--	--
	1991-1999	0-18.8	3.609	-0.275	7.25×10^{-3}	--	--
		18.8-65	1.059	-4.42×10^{-3}	6.82×10^{-5}	--	--
CO	Pre-91&2000+	0-65	1.909	-6.17×10^{-2}	7.25×10^{-4}	-1.73×10^{-6}	--
	1991-1999	0-65	3.034	-0.162	3.32×10^{-3}	-2.31×10^{-5}	--
PM	Pre-91&2000+	0-65	2.653	-0.141	3.29×10^{-3}	-2.51×10^{-5}	--
	1991-1999	0-65	7.000	-0.631	2.27×10^{-2}	2.66×10^{-4}	2.24×10^{-6}
CO2	Pre-91&2000+	0-65	2.132	-9.33×10^{-2}	2.00×10^{-3}	-1.36×10^{-5}	--
	1991-1999	0-65	2.096	-0.108	3.57×10^{-3}	-5.32×10^{-5}	2.89×10^{-7}

The estimated impact of the proposed SCFs to the HHDDT exhaust emissions for the South Coast Air Basin (SCAB) and non-SCAB area are given in Table 7.

Table 7. Estimated Impact on HHDDT Running Exhaust Emissions from Proposed Speed Correction Factors (summer season, tpd)

Aera	Pollutant	2010			2020		
		Current	Proposed	Change	Current	Proposed	Change
South Coast	HC	2.38	2.42	1.5%	1.41	1.43	1.4%
	CO	12.21	10.20	-16%	8.88	7.85	-12%
	NOx	55.25	39.81	-28%	18.58	13.32	-28%
	PM	1.14	1.36	19%	0.62	0.73	18%
All Other Area	HC	2.38	2.63	10%	1.41	1.58	12%
	CO	12.21	10.80	-12%	8.88	8.05	-9.3%
	NOx	55.25	49.20	-11%	18.58	16.02	-14%
	PM	1.14	1.24	9.1%	0.62	0.71	14%

[Note: The final document will include impacts for the San Francisco, Sacramento, San Diego air basins for 2002 and 2015.]

Heavy-Heavy Diesel Truck Idle Emission Rates

Idle emission rates of NOx, HC, and CO for HHDDTs in EMFAC2002 were estimated using test data from nine 1996 -1998 model year HHDDTs tested by WVU. The data were averaged and the averages were assumed to applicable to all model years of trucks. No PM emission data were collected by WVU during the testing of the nine trucks. Therefore, as in EMFAC2000, the PM idle emission factors from U.S. EPA Parts 5 model were used in EMFAC2002. Table 8 shows the EMFAC2002 HHDDT idle emission rates.

Table 8. EMFAC2002 HHDDT Idle Emission Rates (g/hr)

Weight Class	Idle Emission Rate			
	HC	CO	NOx	CO_2
LHDD	3.48	26.3	80.7	4,098
MHDD	3.48	26.3	80.7	4,098
HHDD	3.48	26.3	80.7	4,098

PM Idle Emission Rate* (all heavy-duty trucks)	
Pre-1998	5.37
1988-90	3.17
1991-93	1.86
1994+	1.00

* From Part 5 (U.S. EPA).

The CRC E55/E59 project has provided an opportunity to update idle emission factors for HHDDTs. The E55/E59 data include idle emissions from 25 HHDDTs built between 1973 and 2000 and thus idle emission factors were calculated for model year groups corresponding to the groups for running exhaust emission factors.

In the CRC project, each truck was tested for 15 minutes for idle emissions and each test was repeated three times. Replicate test results were averaged for each truck and the average idle emissions of individual trucks were then subjected a regression analysis to determine the best fit equations that represent the emission trend as a function of model year. Following the grouping of the HHDDT exhaust emission rates, the idle emission rates were calculated for the same model year groups, as shown in Table 9. Because the CRC data were collected at "curb" idle with no accessory loading, the calculated idle emission rates in the table characterize low idle emissions (idling at engine speed ≤ 800 rpm).

Table 9. Proposed HHDDT Low Idle Emission Rates (g/hour)

Model Years	HC	CO	NOx	PM	CO_2
Pre-1975	29.9	36.9	27.9	7.45	4,619
1975-76	26.3	34.9	32.5	6.19	4,619
1977-79	22.3	32.6	38.3	4.92	4,619
1980-83	17.8	29.6	46.4	3.56	4,619
1984-86	14.1	26.9	54.4	2.57	4,619
1987-89	11.3	24.5	62.5	1.86	4,619
1991-93	8.95	22.2	70.5	1.34	4,619
1994-97	7.13	20.2	78.6	0.97	4,619
1998	6.04	18.8	84.4	0.77	4,619
1999-02	5.48	18.1	87.8	0.67	4,619
2003	4.36	16.4	95.9	0.48	4,619
2004-06	4.08	16.0	98.2	0.44	4,619
2007-09	4.08	16.0	98.2	0.24	4,619
2010+	4.08	16.0	98.2	0.044	4,619

Several studies have shown that truck idle emissions are highly dependent on ambient conditions, accessory use, and engine speed. Air conditioning is used during summer and heating during winter. For extended idling, truck operators often set the engine speed at a high rpm (>800 rpm). A recent multi-agency study, which among others included the U.S. EPA and Oak Ridge National Laboratories (ORNL), examined truck idle emissions under different ambient conditions and loads. Using the data obtained from this study, staff calculated high rpm correction factors to obtain the high idle emission rates from low idle rates[3]. Two sets of high idle emission rates were estimated corresponding to summer high temperature months (March through September) and winter low temperature months (October through February), respectively. Tables 10 and 11 show these high idle emission rates.

[3] Staff Report: Heavy-Duty Vehicle Idling Emission Reduction Program (www.arb.ca.gov/regact/hdvidle/hdvidle.htm)

Table 10. HHDDT High Idle Emission Rates for Summer Season (g/hour)

Model Years	HC	CO	NOx	PM	CO_2
Pre-1975	92.7	62.7	58.7	18.6	10,624
1975-76	81.4	59.3	68.3	15.5	10,624
1977-79	69.2	55.4	80.4	12.3	10,624
1980-83	55.1	50.3	97.3	8.91	10,624
1984-86	43.8	45.7	114	6.43	10,624
1987-89	34.9	41.6	131	4.66	10,624
1984-86	43.8	45.7	114	6.43	10,624
1987-89	34.9	41.6	131	4.66	10,624
1998	18.7	32.0	177	1.92	10,624
1999-02	17.0	30.7	184	1.67	10,624
2003	13.5	27.9	201	1.21	10,624
2004-06	12.7	27.2	206	1.10	10,624
2007-09	12.7	27.2	206	0.61	10,624
2010+	12.7	27.2	206	0.11	10,624

Table 11. HHDDT High Idle Emission Rates for Winter Season (g/hour)

Model Years	HC	CO	NOx	PM	CO_2
Pre-1975	218	81.1	50.3	32.0	8,314
1975-76	192	76.8	58.6	26.6	8,314
1977-79	163	71.7	68.9	21.1	8,314
1980-83	130	65.2	83.4	15.3	8,314
1984-86	103	59.2	98.0	11.1	8,314
1987-89	82.2	53.8	112	8.01	8,314
1991-93	65.3	48.9	127	5.78	8,314
1994-97	52.0	44.4	141	4.19	8,314
1998	44.1	41.5	152	3.31	8,314
1999-02	40.0	39.8	158	2.88	8,314
2003	31.8	36.2	173	2.08	8,314
2004-06	29.8	35.2	177	1.90	8,314
2007-09	29.8	35.2	177	1.04	8,314
2010+	29.8	35.2	177	0.19	8,314

To estimate the HHDDT idle emission factors for a given month, the low and high idle emission rates must be weighted by the fraction of time that an average HHDT operates at the low idle conditions and that at the high idle conditions. It has been concluded that for a HHDDT the percentages of low idle and high idle are approximately 61% and 39%, respectively (see note 2 for the detailed discussion).

The estimated impact of the proposed idle emission rates to the HHDDT idle emissions are given in Table 12.

Table 12. Estimated Impact on HHDDT Idle Emissions from Proposed Idle Emission Rates (summer season, tpd)

Air Basin	Pollutant	2010			2020		
		Current	Proposed	Change	Current	Proposed	Change
San Joaquin Valley	HC	0.21	0.76	264%	0.26	0.63	142%
	CO	1.58	1.49	-5.8%	1.98	1.60	-19%
	NOx	4.86	7.20	48%	6.07	10.23	68%
	PM	0.09	0.09	5.1%	0.08	0.07	-10%
South Coast	HC	0.50	1.74	248%	0.60	1.43	138%
	CO	3.79	3.52	-7.2%	4.56	3.67	-19%
	NOx	11.64	17.50	50%	13.99	23.68	69%
	PM	0.21	0.21	0.28%	0.19	0.17	-13%

[Note: The final document will include impacts for the San Francisco, Sacramento, San Diego air basins for 2002 and 2015.]

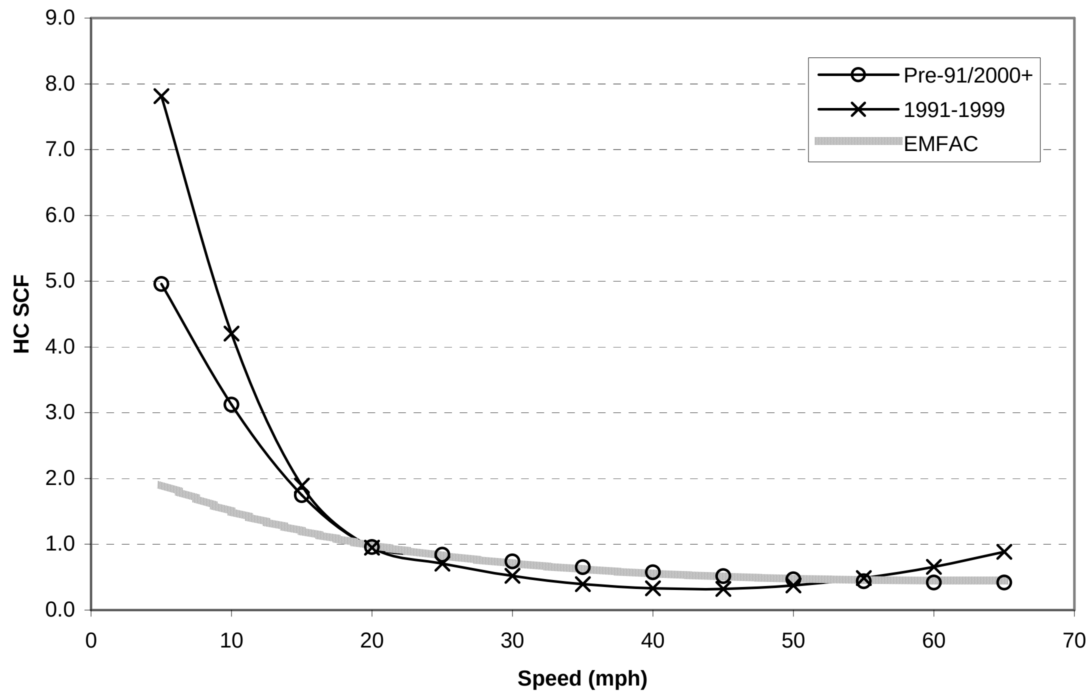
Appendix A. CRC E55/E59 HHDDT UDDS Test Data

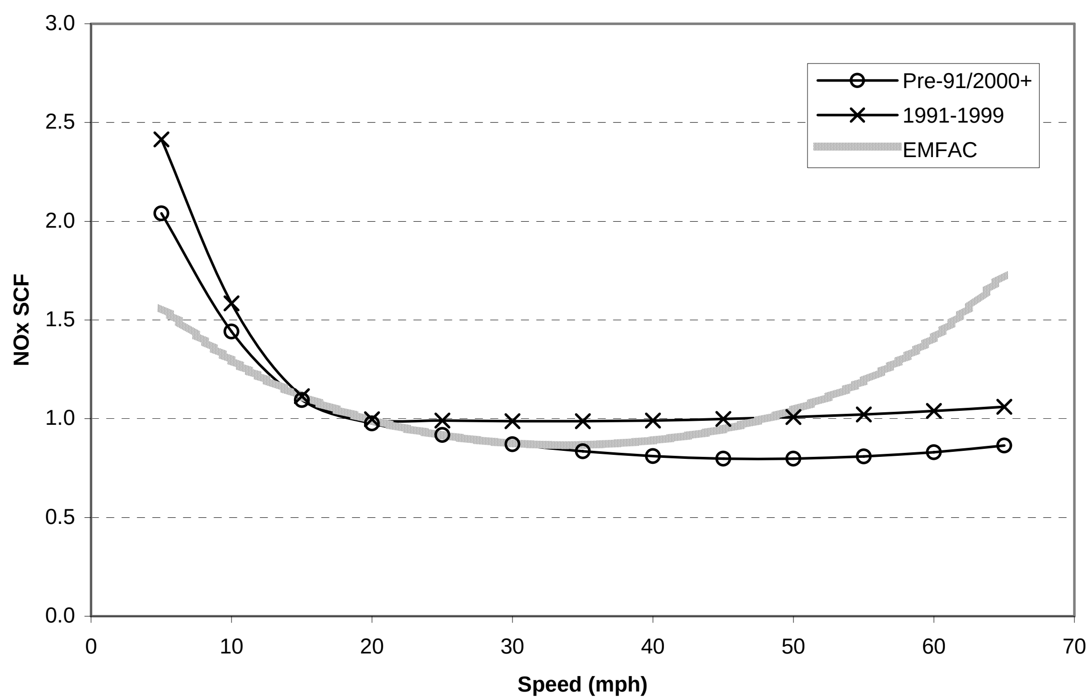
Test ID	Make	Engine Model	Engine MY	Odometer Reading	Vehicle MY	Test Cycle	CO	NOx	HC	PM	CO2
							(g/mile)	(g/mile)	(g/mile)	(g/mile)	(g/mile)
E55CRC-1	Detroit	Diesel Series 60	1994	639,105	1994	UDDS	14.2	36.2	0.24	0.39	1,996
E55CRC-2	Caterpillar	3406B	1995	241,843	1995	UDDS	4.20	20.1	0.84	0.50	2,502
E55CRC-3	Cummins	NTCC-300	1985	501,586	1985	UDDS	13.2	12.4	2.74	1.76	2,203
E55CRC-4	Caterpillar	C-10	2000	42,362	2000	UDDS	9.61	20.4	0.28	0.51	2,523
E55CRC-5	Cummins	N14-435E1	2000	166,980	2000	UDDS	5.35	25.1	1.42	0.53	2,752
E55CRC-6	Cummins	M11-370	1995	689,536	1995	UDDS	9.36	21.0	0.87	0.83	1,954
E55CRC-7	Detroit	Diesel Series 60	1990	399,224	1990	UDDS	6.57	21.5	0.24	0.75	1,991
E55CRC-8	Cummins	M11-300	1996	507,855	1996	UDDS	5.16	25.4	0.83	0.62	2,210
E55CRC-9	Caterpillar	C12	1998	607,968	1998	UDDS	6.98	14.7	0.91	0.97	2,206
E55CRC-10	Detroit	series 60	1998	21,631	1998	UDDS	8.76	39.5	0.22	0.53	2,139
E55CRC-11	Cummins	ISM	2000	117,048	2000	UDDS	2.45	14.1	0.73	0.31	1,942
E55CRC-12	Cummins	300	1986	533,377	1986	UDDS	30.0	18.6	4.42	3.89	2,212
E55CRC-13	Cummins	Cummins 350	1978	570,546	1978	UDDS	18.9	28.1	1.57	1.48	2,302
E55CRC-14	Cummins	LTA10	1985	565,927	1986	UDDS	11.9	18.6	1.13	1.47	2,077
E55CRC-15	Cummins	NTC-350	1986	340,486	1973	UDDS	11.4	27.1	6.98	3.25	2,772
E55CRC-16	Caterpillar	3208	1979	200,000	1979	UDDS	72.7	14.8	1.74	12.1	2,230
E55CRC-17	Cummins	L-10	1993	733,868	1993	UDDS	9.55	17.5	0.92	1.02	2,154
E55CRC-18	Cummins	L-10	1991	440,456	1991	UDDS	5.21	17.5	1.82	0.89	2,102
E55CRC-19	Cummins	L-10	1987	465,061	1987	UDDS	17.0	15.7	4.47	2.01	2,055
E55CRC-20	Detroit	Diesel Series 60	1992	514,188	1992	UDDS	16.6	20.7	0.26	1.12	2,045
E55CRC-21	Caterpillar	3406B	1990	937,438	1990	UDDS	20.5	24.2	0.43	2.97	2,384
E55CRC-22	Cummins	L10-280	1993	232,829	1993	UDDS	4.70	19.0	4.70	0.95	1,980
E55CRC-23	Cummins			320,885	1983	UDDS	33.2	29.5	2.10	2.38	2,393
E55CRC-24	Cummins	NTCC-350	1975	773,487	1975	UDDS	9.88	30.4	2.58	1.19	2,204
E55CRC-25	Cummins		1983	806,068	1983	UDDS	12.4	27.3	2.15	1.33	1,976
E55CRC-26	Caterpillar	C-10	1998	539,553	1999	UDDS	15.0	16.0	0.37	0.81	2,493
E55CRC-27	Detroit	Diesel Series 60	1999	420,927	2000	UDDS	9.44	19.8	0.32	1.21	2,889
E55CRC-28	Detroit	Diesel Series 60	1998	645,034	1999	UDDS	57.5	25.8	0.92	5.24	2,497
E55CRC-29	Cummins	1SX475ST2	1999	120,000	2000	UDDS	8.10	14.1	3.30	3.39	2,395
E55CRC-30	Detroit	Diesel Series 60	1998	138,625	1999	UDDS	10.0	32.8	0.43	0.53	2,155
E55CRC-31	Cummins	N14-460E+	1997	587,389	1998	UDDS	3.15	22.0	2.04	0.50	2,414
E55CRC-32	Caterpillar	3406B	1991	596,082	1992	UDDS	4.53	14.4	0.90	0.81	2,119
E55CRC-33	Caterpillar	3406	1984	988,726	1985	UDDS	12.0	45.1	2.03	2.00	2,268
E55CRC-34	Detroit	Diesel Series 60	2003	19,094	2004	UDDS	6.63	12.8	0.41	1.26	2,446
E55CRC-35	Detroit	Diesel Series 60	2000	106,377	2001	UDDS	6.87	14.9	0.56	0.76	2,017
E55CRC-36	Caterpillar	C-15	2001	284,553	2001	UDDS	6.84	15.0	0.71	0.80	2,409
E55CRC-38	Cummins	ISX	2003	2,829	2004	UDDS	1.04	14.8	0.76	0.17	2,641
E55CRC-39	Cummins	ISX	2003	45	2004	UDDS	1.29	13.0	0.82	0.31	2,582
E55CRC-40	Detroit	Diesel Series 60	2003	8,916	2004	UDDS	0.79	15.8	0.44	0.13	2,148
E55CRC-42	Caterpillar	3406	1999	576,998	2000	UDDS	2.19	14.3	1.00	0.86	2,627
E55CRC-43	Detroit	Diesel Series 60	1994	899,582	1995	UDDS	1.82	21.8	0.32	0.62	1,946
E55CRC-44	Caterpillar	3406	1989	811,202	1989	UDDS	7.88	17.3	0.94	0.84	1,948
E55CRC-45	Cummins	L10-280	1993	685,168	1993	UDDS	3.47	12.2	15.80	3.04	2,029
E55CRC-46	Caterpillar	3176	1989	935,582	1989	UDDS	7.60	16.2	0.35	1.43	2,067
E55CRC-47	Detroit	6V92	1986	760,810	1986	UDDS	7.59	13.3	1.24	2.82	2,272
E55CRC-48	Cummins	N1 Plus	1998	753,792	1998	UDDS	2.11	24.2	1.42	0.77	2,407
E55CRC-49	Caterpillar		1993	650,557	1994	UDDS	12.9	15.2	0.40	1.92	2,085

Appendix B. CRC E55/E59 HHDDT Idle Emission Test Data

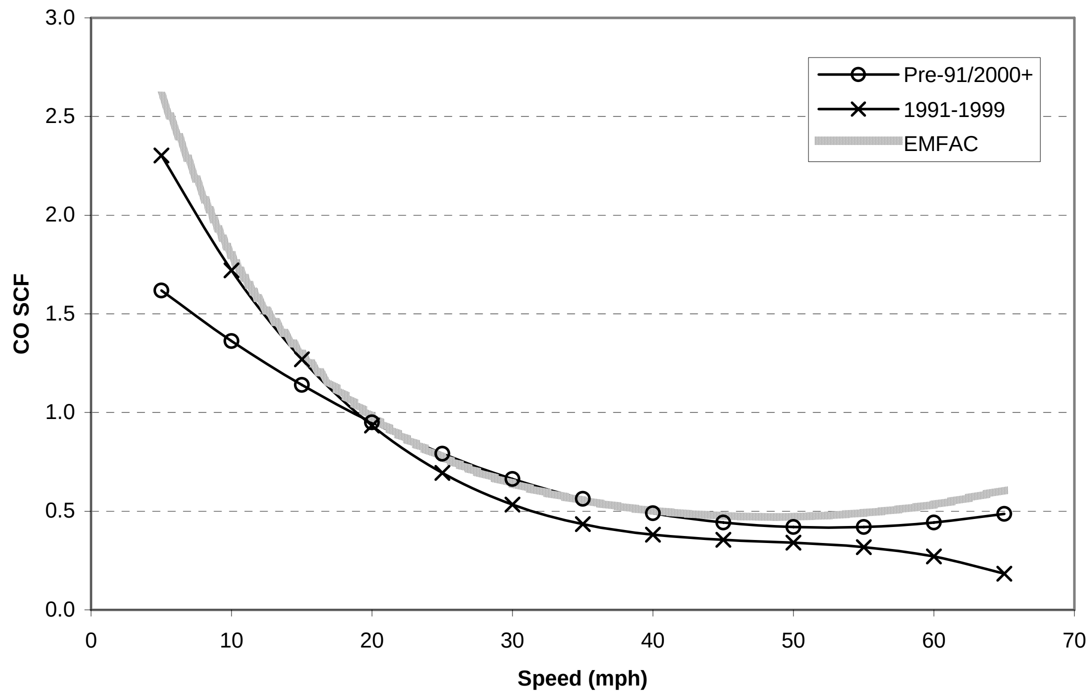
Test ID	Make	Engine Model	Engine MY	Odometer Reading	Vehicle MY	Test Cycle	CO	NOx	HC	PM	CO2
							g/min	g/min	g/min	g/min	g/min
E55CRC-1	Detroit	Diesel Series 60	1994	639,105	1994	Idle32	0.230	1.33	0.070	0.010	73.2
E55CRC-2	Caterpillar	3406B	1995	241,843	1995	Idle32	0.340	1.79	0.150	0.060	88.6
E55CRC-3	Cummins	NTCC-300	1985	501,586	1985	Idle32	1.33	0.36	0.320	0.140	75.2
E55CRC-4	Caterpillar	C-10	2000	42,362	2000	Idle32	1.58	1.66	0.050	0.010	114
E55CRC-5	Cummins	N14-435E1	2000	166,980	2000	Idle32	0.230	1.60	0.180	0.020	84.9
E55CRC-6	Cummins	M11-370	1995	689,536	1995	Idle32	0.180	1.56	0.110	0.030	69.7
E55CRC-7	Detroit	Diesel Sseries 60	1990	399,224	1990	Idle32	0.130	1.33	0.050	0.000	60.0
E55CRC-8	Cummins	M11-300	1996	507,855	1996	Idle32	0.270	1.32	0.140	0.030	84.0
E55CRC-9	Caterpillar	C12	1998	607,968	1998	Idle32	0.340	1.02	0.080	0.020	63.6
E55CRC-10	Detroit	series 60	1998	21,631	1998	Idle32	0.470	1.33	0.090	0.010	70.0
E55CRC-11	Cummins	ISM	2000	117,048	2000	Idle32	0.230	0.89	0.110	0.010	59.6
E55CRC-12	Cummins	300	1986	533,377	1986	Idle32	0.560	0.41	0.700	0.100	76.1
E55CRC-13	Cummins	Cummins 350	1978	570,546	1978	Idle32	0.530	0.64	0.150	0.050	83.8
E55CRC-14	Cummins	LTA10	1985	565,927	1986	Idle32	0.320	0.22	0.140	0.080	57.6
E55CRC-15	Cummins	NTC-350	1986	340,486	1973	Idle32	0.680	0.23	0.840	0.190	83.9
E55CRC-16	Caterpillar	3208	1979	200,000	1979	Idle32	0.640	1.11	0.110	0.010	62.5
E55CRC-17	Cummins	L-10	1993	733,868	1993	Idle32	0.080	0.97	0.060	0.030	64.1
E55CRC-18	Cummins	L-10	1991	440,456	1991	Idle32	0.720	1.19	0.480	0.090	67.6
E55CRC-19	Cummins	L-10	1987	465,061	1987	Idle32	0.580	0.37	0.450	0.100	65.2
E55CRC-20	Detroit	Diesel Series 60	1992	514,188	1992	Idle32	0.260	1.35	0.070	0.010	68.3
E55CRC-21	Caterpillar	3406B	1990	937,438	1990	Idle32	0.720	1.46	0.100	0.020	66.5
E55CRC-22	Cummins	L10-280	1993	232,829	1993	Idle32	0.470	1.07	0.990	0.070	67.2
E55CRC-23	Cummins			320,885	1983	Idle32	0.630	0.555	0.560	0.060	79.3
E55CRC-24	Cummins	NTCC-350	1975	773,487	1975	Idle32	0.310	0.595	0.330	0.030	67.8
E55CRC-25	Cummins		1983	806,068	1983	Idle32	0.350	0.560	0.390	0.050	69.4
E55CRC-26	Caterpillar	C-10	1998	539,553	1999	Idle32	0.350	1.03	0.066	0.004	70.7
E55CRC-27	Detroit	Diesel Series 60	1999	420,927	2000	Idle32	0.462	2.50	0.048	0.010	90.8
E55CRC-28	Detroit	Diesel Series 60	1998	645,034	1999	Idle32	0.503	2.05	2.027	0.024	58.7
E55CRC-29	Cummins	1SX475ST2	1999	120,000	2000	Idle32	0.375	0.749	0.229	0.110	95.9
E55CRC-30	Detroit	Diesel Series 60	1998	138,625	1999	Idle32	0.543	1.70	0.050	0.010	70.5
E55CRC-31	Cummins	N14-460E+	1997	587,389	1998	Idle32	0.269	1.84	0.300	0.018	82.1
E55CRC-32	Caterpillar	3406B	1991	596,082	1992	Idle32	0.436	0.807	0.178	0.022	83.4
E55CRC-33	Caterpillar	3406	1984	988,726	1985	Idle32	0.448	1.85	0.236	0.044	74.7
E55CRC-34	Detroit	Diesel Series 60	2003	19,094	2004	Idle32	0.373	1.86	0.035	0.001	91.5
E55CRC-35	Detroit	Diesel Series 60	2000	106,377	2001	Idle32	0.408	1.33	0.110	0.016	76.4
E55CRC-36	Caterpillar	C-15	2001	284,553	2001	Idle32	0.299	1.33	0.098	0.004	99.7
E55CRC-38	Cummins	ISX	2003	2,829	2004	Idle32	0.168	1.06	0.108	0.010	82.8
E55CRC-39	Cummins	ISX	2003	45	2004	Idle32	0.128	1.17	0.115	0.006	86.7
E55CRC-40	Detroit	Diesel Series 60	2003	8,916	2004	Idle32	0.142	1.29	0.071	0.003	66.5
E55CRC-41	Cummins	B5.9 210	1997	13,029	1998	Idle32	0.408	1.36	0.142	0.005	65.5
E55CRC-42	Caterpillar	3406	1999	576,998	2000	Idle32	0.184	1.16	0.077	0.022	97.9
E55CRC-43	Detroit	Diesel Series 60	1994	899,582	1995	Idle32	0.596	1.08	0.094	0.008	74.7
E55CRC-44	Caterpillar	3406	1989	811,202	1989	Idle32	0.274	1.75	0.154	0.012	77.3
E55CRC-45	Cummins	L10-280	1993	685,168	1993	Idle32	1.13	0.735	4.267	0.493	69.9
E55CRC-46	Caterpillar	3176	1989	935,582	1989	Idle32	0.141	1.65	0.018	0.010	76.0
E55CRC-47	Detroit	6V92	1986	760,810	1986	Idle32	0.202	1.09	0.485	0.025	84.2
E55CRC-48	Cummins	N1 Plus	1998	753,792	1998	Idle32	0.231	3.30	0.011	0.040	119
E55CRC-49	Caterpillar		1993	650,557	1994	Idle32	0.203	1.04	0.040	0.008	85.9

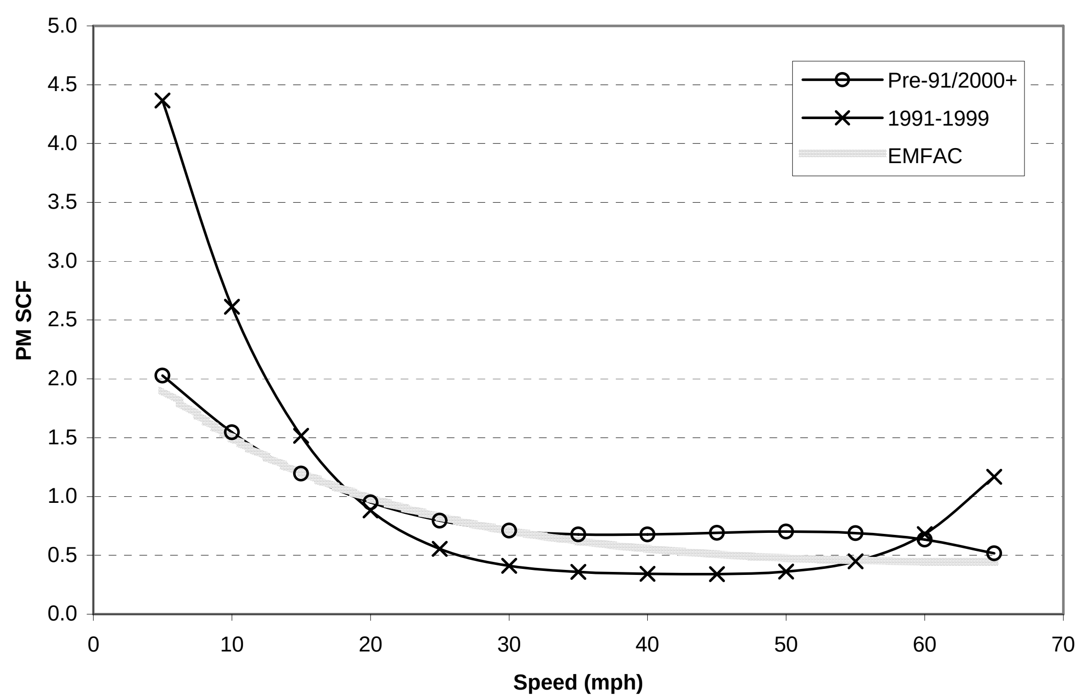
Appendix C. Proposed HHDT SCFs as Compared with SCFs in EMFAC





Appendix C (continued)





Appendix 3 (continued)